

# STUDY OF MULTIPARTICLE PRODUCTION BY GLUON DOMINANCE MODEL (Part II) <sup>1</sup>

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## Abstract

The gluon dominance model presents a description of multiparticle production in proton-proton collisions and proton-antiproton annihilation. The collective behavior of secondary particles in  $pp$ -interactions at 70 GeV/c and higher is studied in the project "Thermalization". The obtained neutral and charged multiplicity distribution parameters explain some RHIC-data. The gluon dominance model is modified by the inclusion of intermediate quark topology for the multiplicity distribution description in the pure  $p\bar{p}$ -annihilation at few tens GeV/c and explains behavior of the second correlative moment. This article proposes a mechanism of the soft photon production as a sign of hadronization. Excess of soft photons allows one to estimate the emission region size.

## 1 Introduction

A new model of investigating multiparticle production (MP) at high energy is proposed. It is based on multiplicity distribution (MD) description of different interactions on basis of QCD and a phenomenological hadronization scheme. It is shown that the proposed model agrees with experimental data in a wide energy region and, perhaps, can be used for analysis of jet quenching and other phenomena at RHIC [1].

Application of this model approach to  $pp$ -interaction (for the beginning see [2]) is given in Section 2. The additional investigations of MD in the  $p\bar{p}$  annihilation channel at a few tens GeV/c are carried out in Section 3. The emission region size for soft photons and the possible mechanisms of their formation are discussed in Section 4. The main results of these studies are given in Section 5.

## 2 MD in $pp$ -interactions (continuation)

MD of charged particles in proton interactions by means of the gluon dominance model were studied in [2]. It is interesting to get MD for neutral mesons. For this purpose we take experimental mean multiplicity of  $\pi^0$  in  $pp$ -interactions at 69 GeV/c ( $\sqrt{s} \simeq 11.6$  GeV). It was be found  $2.57 \pm 0.13$  [3]. So the mean multiplicity in this process is calculated as the product of the mean number of evaporated active gluons ( $\overline{m} = 2.48$ ) and hadron parameter  $\overline{n}^h$ . We can determine the hadronization parameter for neutral mesons:

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$\bar{n}_0 = 1.036 \pm 0.041$  [4]. We expect approximate equality of probabilities of different hadron production at the second (hadronization) stage. MD for neutral mesons have a form as for charged particles [2]:

$$P_n(s) = \sum_{m=0}^{ME} \frac{e^{-\bar{m}} \bar{m}^m}{m!} C_{mN}^{n-2} \left( \frac{\bar{n}^h}{N} \right)^{n-2} \left( 1 - \frac{\bar{n}^h}{N} \right)^{mN-(n-2)}, \quad (1)$$

and can be easily obtained if they are normalized to mean multiplicity  $\pi^0$ 's (Fig. 1). From this distribution we see that the maximal possible number of  $\pi^0$  from TSTM [4] is 16. MD for the total multiplicity are shown in Fig. 2. The maximal total number of particles in this case is equal to 42.

The dependence of the mean multiplicity of neutral mesons  $\bar{n}_0$  versus the number of charged particles  $n_{ch}$  can be determined by means of MD  $P_{n_{tot}}(s)$ :

$$\bar{n}_0(n_{ch}, s) = \frac{\sum_{n_{tot}=n_1}^{n_2} P_{n_{tot}}(s) \cdot (n_{tot} - n_{ch})}{\sum_{n_{tot}=n_1}^{n_2} P_{n_{tot}}(s)}, \quad (2)$$

where  $n_1$  and  $n_2$  are lower and top boundaries for the total multiplicity at the given number of charged particles  $n_{ch}$ . The MD of charged and neutral secondaries obtained by TSTM give the maximal number for charged  $n_{ch} = 26$ , neutral  $n_0 = 16$  and total  $n_{tot} = 42$ . That is why we have the following limits for  $n_1$  and  $n_2$ :  $n_1 \geq n_{ch}$ ,  $n_2 \leq 16 + n_{ch}$ . These restrictions result in great disagreement with experimental data [3] at small multiplicities. It was shown in [4].

A significant improvement will be reached if we decrease the top limit at low multiplicities ( $n_{ch} \leq 10$ ) to  $n_2 = 2n_{ch}$ . This corresponds to the case when the maximal number of neutrals is equal to the number of charged particles, and a double excess of neutral mesons over positive (negative) pions is possible. Fig. 3 shows that multiplicity of neutrals versus  $n_{ch}$  when  $n_2$  is taken equal to  $2n_{ch}$  at small  $n_{ch}$  and  $n_2 = 16 + n_{ch}$  at  $n_{ch} > 10$ . This restriction in (2) indicates that AntiCentauro events (a large number of neutrals and very few charged particles) must be absent. Centauro events (a large number of charged particles and practically no accompanying neutrals) may be realized only in the region of high multiplicity.

It is assumed [5] that at the second stage different kinds of quark pairs from the gluon (maximal possible number is equal to  $N_{tot}$ ) occur with equal probabilities. We will try to consider the formation of neutral and charged mesons as an example of the above assumption. The  $u\bar{u}$  and  $d\bar{d}$  quark pairs may appear at sufficient energy. At the end of hadronization the formation of two charged mesons (the law of charge conservation of quarks) may take place. Production of an additional neutral particle is not necessary while formation of a neutral meson. So we can claim that the number of charged hadrons will be larger than the number of the neutral ones, or the probability of the charged hadron production is higher than of the neutral ones. We can estimate these probabilities in GDM.

MD of  $\pi^0$  from one gluon at the second stage may be described by the binomial distribution  $P_{n_0} = C_{n_t}^{n_0} p_0^{n_0} p_c^{n_t-n_0}$ . Here  $n_t$  is the total number of hadrons formed from gluon,  $n_0$  - the number of neutral mesons among these secondaries (the number of charged hadrons  $n_c = n_t - n_0$ ),  $p_c(p_0)$  - the probability of production of charged pair (one  $\pi^0$ ).

The normalized condition is  $p_0 + p_c = 1$ . From TSTM we have obtained  $\bar{n}_{ch} = 1.63$  and  $\bar{n}_0 = 1.036$ . The mean multiplicities for binomial distributions will be equal to:  $\bar{n}_{ch} = p_c \bar{n}_t$ ,  $\bar{n}_0 = p_0 \bar{n}_t$ . The probability of the charge particle production is higher than of the neutral mesons ( $\bar{n}_{ch} > \bar{n}_0$ ). The ratio of these values is  $p_c/p_0 \sim 1.46$ .

The mean multiplicity of newly born hadrons (charged or neutral) in proton interactions in GDM is equal to the product of the mean multiplicity of gluons obtained at the first stage and the mean multiplicity of hadrons ( $\bar{n}_{ch}^h$  or  $\bar{n}_0^h$ ) produced from one gluon at the second stage. In the case of binomial distribution  $\bar{n}_{ch} = \bar{n}_t \cdot p_c$ ,  $\bar{n}_0 = \bar{n}_t \cdot p_0$ . Taking into account two leading protons, the mean multiplicity is  $\bar{n}_{ch}(s) = 2 + \bar{m}_g(s) \cdot \bar{n}_{ch}^h$  for charged particles in pp-interactions. The mean multiplicity of neutral mesons in this process is  $\bar{n}_0(s) = \bar{m}_g(s) \cdot \bar{n}_0^h$ . The ratio of the mean charged pairs to the neutral mesons in proton interactions is

$$\frac{\bar{n}_{ch}(s)/2}{\bar{n}_0} = \frac{1}{\bar{m}(s) \cdot \bar{n}_0^h} + \frac{1}{2} \cdot \frac{\bar{n}_{ch}^h}{\bar{n}_0^h}. \quad (3)$$

At 69 GeV/c this ratio (3) is equal to  $1.19 \pm .25$ . At the higher energy the mean number of active gluons  $\bar{m}$  increases and becomes much more than 3. In this case (3) it will be around the ratio of  $\bar{n}_{ch}^h/2\bar{n}_0^h$ . The experimental data have shown 1.6 for Au-Au peripheral interactions (80 – 92(%) centrality class) at 200 GeV and for pp interactions at 53 GeV [6]. We can compare these results with GDM at higher energies.

The application of GDM to describe MD in the energy region (102, 205, 300, 405 and 800 GeV/c) [7] in both schemes (TSMB and TSTM) [2] leads to good results (Fig. 4-8). Parameters of TSTM in this domain are given in Table 2.

Table 1. Parameters of TSTM.

$\sqrt{s}$ GeV	$\bar{m}$	$M_g$	$N$	$\bar{n}^h$	$\Omega$	$\chi^2/\text{ndf}$
102	$2.75 \pm 0.08$	8	$3.13 \pm 0.56$	$1.64 \pm 0.04$	$1.92 \pm 0.08$	2.2/5
205	$2.82 \pm 0.20$	8	$4.50 \pm 0.10$	$2.02 \pm 0.12$	$2.00 \pm 0.07$	2.0/8
300	$2.94 \pm 0.34$	10	$4.07 \pm 0.86$	$2.22 \pm 0.23$	$1.97 \pm 0.05$	9.8/9
405	$2.70 \pm 0.30$	9	$4.60 \pm 0.24$	$2.66 \pm 0.22$	$1.98 \pm 0.07$	16.4/12
800	$3.41 \pm 2.55$	10	$20.30 \pm 10.40$	$2.41 \pm 1.69$	$2.01 \pm 0.08$	10.8/12

We see that the number of active gluons and their mean multiplicity increase, parameters of hadronization  $N$  and  $\bar{n}_{ch}^h$  vary very slowly. At these energies the charged hadron/pion ratio (3) grows up to 1.6. The parameter of hadronization  $\bar{n}_{ch}^h$  has a trend to increase weakly but  $\bar{n}_0^h$  does not almost change. This behavior may be related with the production of other charged particles (not only pions): protons, antiprotons, kaons and so on. We consider that parameter  $\bar{n}_{ch}^h$  goes to the limit value (like saturation).

On the other side a small growth  $\bar{n}_g^h$  in proton interactions also points at a possible change mechanism of hadronization of gluons in comparison with the transition gluons to hadrons in  $e^+e^-$  annihilation. It is considered that in the last case partons transform to hadrons by the fragmentation mechanism at the absence of the thermal medium. Our MD analysis gives  $\bar{n}_g^h \sim 1$  for this fragmentation [8]. The recombination is specific for the hadron and nucleus processes. In this situation a lot of quark pairs from gluons appear almost simultaneously and recombine to various hadrons [9]. The value  $\bar{n}_g^h$  becomes bigger  $\sim 2 - 3$ , that indicates to the transition from the fragmentation mechanism to

the recombination one. The recombination mechanism provides justification for applying the statistical model to describe ratios of hadron yields (the ratio  $Baryon/Meson \approx 1$ ) [9]. The collective flow of quarks may be explained by the recombination mechanism, too. The rapid local thermalization may be a consequence of this formation of secondary hadrons [9].

In this way we try to compare two kinds of processes which have different values of hadronization parameters. The first one is  $e^+e^-$  - annihilation. It is usually supposed that fragmentation dominates in it and newly formed hadrons fragment with a high moment of parton into the surrounding vacuum (such objects can also appear from the hot surface in peripheral events in nucleus and hadron collisions) [9].

The nuclear modification factor  $R_{CP}$  and elliptic flow  $v_2$  in Au-Au collisions at RHIC have revealed an apparent quark-number dependence in the  $p_T$  region from 1.5 to 5 GeV/c. Moreover, the baryon production increases more rapidly with centrality than the meson production. These observations confirm the picture of hadron formation by quark recombination [9] and point out that the hadronization processes in high energy nucleus interactions are modified to the comparison of  $e^+ + e^-$  and partly  $p + p$  collisions.

The GDM with a branch gives growth of the part of the evaporated gluons to 0.85-0.98 and a small rise of gluon branch number at higher energies. Besides we have got data about emergence of hard constituent in MP [10]. In GDM it can be explained not only by not only evaporation of a single gluon sources but also of groups with several gluons (formed by branch). A simple MD scheme of this superposition will be analyzed below.

Let us compare MD (1) with the descriptions of experimental data obtained by various approaches. We bring two of them. A fortunate expression for KNO function was obtained by a group from IHEP [11] who combined the elastic and inelastic processes. We can see (Fig. 9) good agreement with data [7] at 800 GeV/c both of MD in MGD (solid line) and KNO-function (dot line).

A wide research of MD in pp-interactions was fulfilled by L.Van Hove, A.Giovannini and R.Ugoccioni [10]. They proposed a two-step mechanisms of MP. The independent (Poisson) production of groups of ancestor particles (named "clan ancestors") were supplemented by their decay, according to a hadron shower process (the logarithmic MD within each clan). Such convolution of two mechanisms gives a negative binomial distribution (NBD) for hadrons

$$P_n(s) = \frac{k_h(k_h + 1) \dots (k_h + n - 1)}{n!} \left( \frac{\bar{n}(s)}{\bar{n}(s) + k_h} \right)^n \left( \frac{k_h}{k_h + \bar{n}(s)} \right)^{k_h}, \quad (4)$$

where  $k_h$  - the NBD parameter and  $\bar{n}(s)$  - the mean multiplicity of hadrons. The comparison of NBD (dot line) and our MD in GDM (solid line) with data at 800 GeV/c is given in Fig. 10. A. Giovannini emphasizes that the nature of this clan is gluon bremsstrahlung [10]. Our investigations by GDM allows to give a concrete gluon content. Binomial distributions (BD) describe the hadronization stage. The clan model of [10] uses the logarithmic distribution of secondaries in a single clan. Both of MD have the similar behavior.

At the top energy (especially at 900 GeV) the shoulder structure appears in  $P_n$  [12]. The comparison of data with one NBD does not describe data well. But the weighted superposition of two NBD gives a good description of the shoulder structure  $P_n(s)$  [10]. At 14 TeV A.Giovannini expects the weighted superposition of the three classes of events.

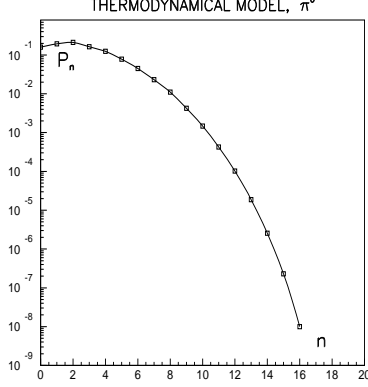


Figure 1: MD for  $\pi^0$ .

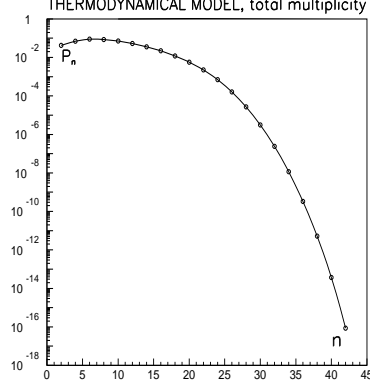


Figure 2: MD for  $n_{tot}$ .

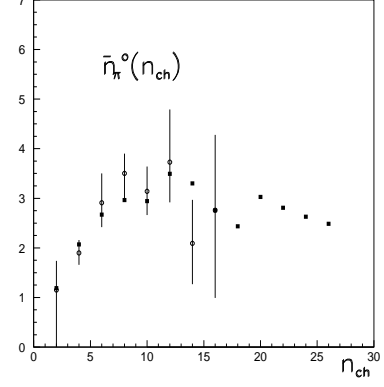


Figure 3:  $\bar{n}_\pi^0(n_{ch})$ .

We can modify our GDM considering that the gluon fission may be realized at higher energies. The independent evaporation of gluons sources of hadrons may be realized by single gluons and also groups from two and more fission gluons. Following A.Giovannini we name such groups of gluons - clans. Their independent emergence and following hadronization content of GDM. MD in GDM with two kinds of clans are:

$$P_n(s) = \alpha_1 \sum_{m_1=0}^{Mg_1} \frac{e^{-\bar{m}_1} \bar{m}_1^{m_1}}{m_1!} C_{m_1 \cdot N}^{m-2} \left( \frac{\bar{n}^h}{N} \right)^{n-2} \left( 1 - \frac{\bar{n}^h}{N} \right)^{m_1 \cdot N - (n-2)} +$$

$$+ \alpha_2 \sum_{m_2=0}^{Mg_2} \frac{e^{-\bar{m}_2} \bar{m}_2^{m_2}}{m_2!} C_{2 \cdot m_2 \cdot N}^{m-2} \left( \frac{\bar{n}^h}{N} \right)^{n-2} \left( 1 - \frac{\bar{n}^h}{N} \right)^{2 \cdot m_2 \cdot N - (n-2)}, \quad (5)$$

where  $\alpha_1$  and  $\alpha_2$  are the contribution single and double gluon clans ( $\alpha_1 + \alpha_2 = 1$ ). The comparison (5) with experimental data for proton interactions at  $\sqrt{s} = 62.2$  GeV [13] is given in Fig. 8. We have obtained the following values of parameters:  $N = 7.06 \pm 3.48$ ,  $\bar{m}_1 = 3.59 \pm 0.03$ ,  $\bar{m}_2 = 1.15 \pm 0.25$ ,  $\bar{n}_h = 3.23 \pm 0.14$ ,  $Mg_1 = 8$ ,  $Mg_2 = 4$ ,  $\alpha_1/\alpha_2 \sim 1.8$  at  $\chi^2/\text{ndf} = 9.12/13$ . The mean multiplicities of the two kinds of clans are similar.

The specific feature of our GDM approach is the dominance of a lot of active gluons in MP. We can expect the emergence of them in nucleus collisions (experiments at RHIC) and the formation of a new kind of matter (quark-gluon plasma) at high energy. We consider that our gluon system can be a candidate for this. So the mean multiplicity of active gluons approached 10 at RHIC. For Au+Au central collisions their number may be equal to  $200 \cdot \bar{m} \approx 2000$  before the branch. This gluon medium facilitates the quenching.

### 3 MD in $p\bar{p}$ -annihilation

In the midst of interesting and enough inextricable hadron interactions the  $p\bar{p}$  annihilation shows up especially [14]. Experimental data at tens GeV/c [14] point out on some maxima in differences between  $p\bar{p}$  and  $pp$  inelastic topological cross sections what may witness about the contribution of different mechanisms of MP

$$\Delta\sigma_n(p\bar{p} - pp) = \sigma_n(p\bar{p}) - \sigma_n(pp). \quad (6)$$

The important information about the MP mechanism may be picked out from the MD moment analysis of charged particles. The second correlative moment for negative particles  $f_2^{--}$  are available to study MP

$$f_2^{--} = \overline{n_-(n_- - 1)} - \bar{n}_-^2. \quad (7)$$

The negative value of second correlative moments is characteristic for a more narrow MD than Poisson, and they indicate the predominance of the hadronization stage in MP. According to MGD, active gluons are a basic source of secondary hadrons.

At the initial stage of annihilation three valent  $q\bar{q}$ -pairs ( $uud$  and  $\bar{u}\bar{u}\bar{d}$ ) are. They can turn to the "leading" mesons which consist from: a) valent quarks or b) valent and vacuum quarks [5]. In the case a) only three "leading" neutral pions (the "0" topology) or two charged and one neutral "leading" mesons ("2" - topology) may form. In b) case the "4"- and "6"- topology is realized for "leading" mesons. We suggest that the formation neutron and antineutron (exchange) can be realized.

A simple scheme of MP for annihilation may give the negative second correlative moments in GDM. We suggest that the active gluon emergence together with the formation of intermediate topology occurs. The GF for a single active gluon  $Q_1(z) = [1 + \bar{n}/N(z-1)]^N$  gives [4]

$$f_2 = Q_1''(z)|_{z=1} - [Q_1(z)|_{z=1}]^2 = -(\bar{n}^h)^2/N < 0. \quad (8)$$

Reciprocally for  $m$  gluons GF and  $f_2$  will be

$$Q_m(z) = [1 + \bar{n}^h/N(z-1)]^{mN}, \quad f_2 = -m(\bar{n}^h)^2/N. \quad (9)$$

We consider that  $m$  grows while increasing the energy of the colliding particles, and  $f_2$  will decrease almost linearly from  $m$ . Such behavior qualitatively agrees with experimental data [14]. If we take concrete MD  $P_m^G$  for gluons, then GF for secondary hadrons and  $f_2$  are

$$Q(z) = \sum_m P_m^G [1 + \bar{n}^h/N(z-1)]^{mN} \quad (10)$$

$$f_2 = [f_2^G + 1 - 1/N] \cdot \bar{m} \cdot (\bar{n}^h)^2, \quad f_2^G = \overline{m(m-1)} - \bar{m}^2, \quad (11)$$

where  $f_2^G$  - the second correlative moment for gluons. In this scheme  $f_2$  may be negative or positive. We consider that the negative value  $f_2$  in the large energy region in comparison with  $p+p$  interactions may be related with the destruction of the initial system on three or more shares and the number of active gluons related with a "leading" pion will be less than in the case of a leading proton in  $pp$ -collisions at the same energy. Herewith the total number of such gluons at annihilation may be bigger, their manifestation happens independently but the number of them per one pion grows slowly. The explanation of the negative  $f_2$  was given R.Lednicky [15] at the assumption of the independent MP of charged particles. The second correlative moment has a zero value only in the small energy domain. And so we should restrict the region to apply this explanation.

According to GDM for  $p\bar{p}$  annihilation and taking into account three intermediate charged topology and active gluons, GF  $Q(z)$  for final MD may be written as the convolution gluon and hadron components:

$$Q(z) = c_0 \sum_m P_m^G [1 + \frac{\bar{n}^h}{N}(z-1)]^{mN} + c_2 \sum_m z^2 P_m^G [1 + \frac{\bar{n}^h}{N}(z-1)]^{mN} + c_4 \sum_m z^4 P_m^G [1 + \frac{\bar{n}^h}{N}(z-1)]^{mN}.$$

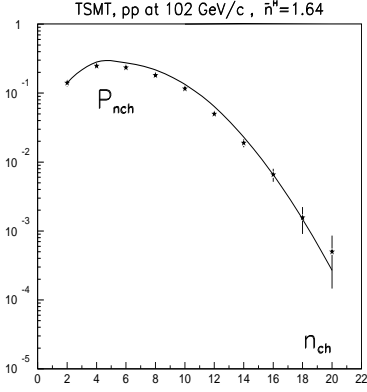


Figure 4: MD at 102 GeV/c.

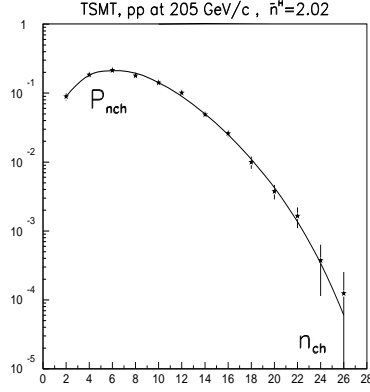


Figure 5: MD at 205 GeV/c.

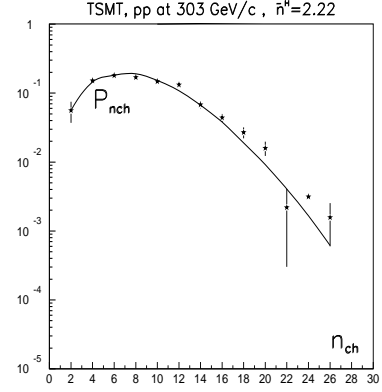


Figure 6: MD at 303 GeV/c.

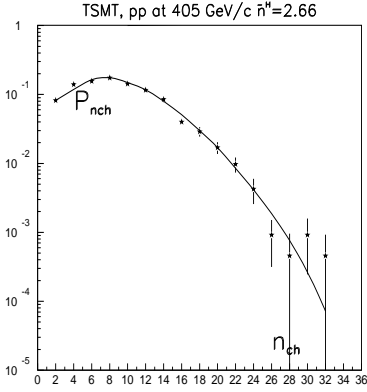


Figure 7: MD at 405 GeV/c.

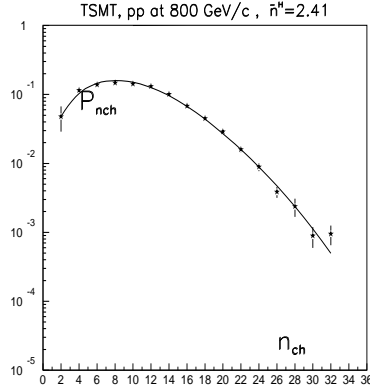


Figure 8: MD at 800 GeV/c.

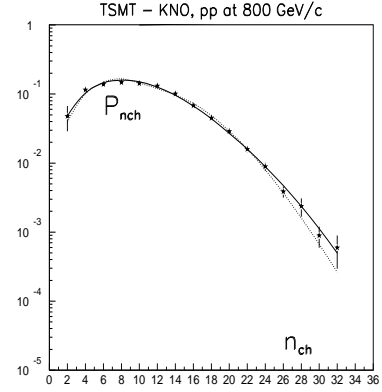


Figure 9: MD in GDM and KNO-function [11].

The parameters of  $c_0$ ,  $c_2$  and  $c_4$  are determined as the part of intermediate topology ("0", "2" or "4") to the annihilation cross section ( $c_0 + c_2 + c_4 = 1$ ). For the simplicity we are limited by Poisson distribution with the finite number of gluons for  $P_m^G$ .

The comparison of the experimental data (Fig. 12) gives the following values of parameters:  $\bar{m} = 3.36 \pm 0.18$ ,  $N = 4.01 \pm 0.61$ ,  $\bar{n}^h = 1.74 \pm 0.26$ , the ratio  $c_0 : c_2 : c_4 = 15 : 40 : 0.05$  at  $\chi^2/ndf = 5.77/4$  and the maximum possible number of gluons  $M = 4$  at "4"-topology. The sum begins from  $m = 1$  (inelastic events), at  $n \geq 2$  - from  $m = 0$  and finishes up  $m < M$  at small multiplicities ( $n \leq 4$ ). We should to emphasize very complicated events  $n_{ch} = 0$  and 2. This research of  $p\bar{p}$  annihilation requires to be continued. We will develop MGD to describe MD at energies 200, 500, 900 GeV [16] and higher.

## 4 Soft photons

The production of photons in particle collisions at high energies was studied in many experiments [17]. In project "Thermalization" it is planned to investigate low energetic photons with  $p_t \leq 0.1 \text{ GeV}/c$  and  $x \leq 0.01$  [18]. Usually these photons are named soft photons (SP). Experiments shown that measured cross sections of SP are several times larger than the expected ones from QED inner bremsstrahlung. Phenomenological models

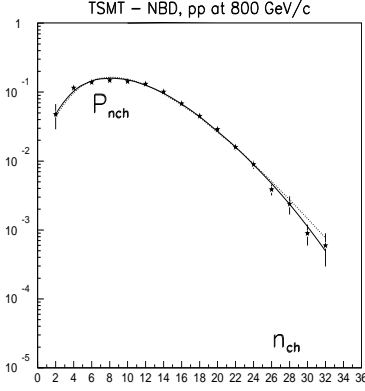


Figure 10: MD in TSTM and NBD.

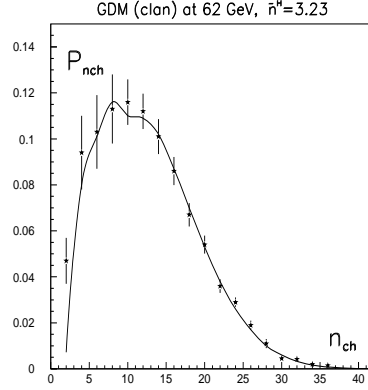


Figure 11: MD in GDM (clan).

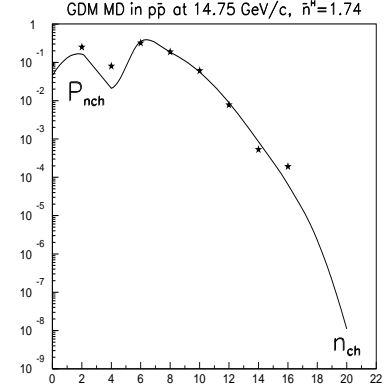


Figure 12: GDM MD in  $p\bar{p}$  at 14.75 GeV/c.

were proposed to explain the SP excess: the glob model of Lichard and Van Hove and the modified soft annihilation model of Lichard and Thomson [19] .

We consider that at a certain moment QGS or excited new hadrons may set in an almost equilibrium state during a short period or finite time. That is why, to describe massless photons, we will try to use the black body emission spectrum [20]. From experimental data [18] the inelastic cross section is equal to approximately  $40mb$ , the cross section of SP formation is about  $4mb$ , and since  $\sigma_\gamma \simeq n_\gamma(T) \cdot \sigma_{in}$ , then the number of SP will be equal to  $n_\gamma \approx 0.1$ . For convenience, we may use the well-known density of MVB at  $T_r = 2.275K$  and get the number of photons by means of MVB  $n_\gamma(T) = n_\gamma(T_r) \cdot \left(\frac{T}{T_r}\right)^3$ . The density of SP in the region  $1fm^3$  will be equal to

$$\rho(T) = n_\gamma(T)/V = 4.112 \cdot 10^8 \cdot 10^{-6} \cdot 10^{-39} \cdot \left(\frac{T}{T_r}\right)^3 fm^{-3}.$$

The estimates of temperature are implemented by transfer moment:  $T = p \approx p_T \sqrt{2}$  ( $1MeV = 1.16 \cdot 10^{10}K$ ). If  $T(p_T)$  is known, using  $n_\gamma$  we can estimate the linear size of radiation system ( $V \simeq L^3$ ). Dependencies of the linear size of system (L) from the SP moment ( $p_T$ ) are given in Table 2.

Table 2. The size of system L (fm) versus  $p_T$  (MeV/c) of SP.

$p_T$	10	15	25	30	40	50
$L$	11	6.9	4.1	3.5	2.6	2.0

It is well-known that the temperature of second hadrons is higher than the temperature of SP. We presume that objects with soft gluon content may not transform into hadrons but turn into SP. The amount of such soft gluons is estimated by  $N_g$  in TSMB.

## 5 Conclusion

In our research we have undertaken an attempt to give MP description in different processes by means of a unified approach based on quark-gluon picture using the phenomeno-



logical hadronization model. The implemented model investigation allows us to understand deeper the picture of MP at various stages. We have obtained qualitative and quantitative agreements of our schemes with experimental data in  $e^+e^-$ ,  $p\bar{p}$  annihilation and  $pp$  and nucleus collisions in a very wide energy domain.

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